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BATS OF BARBUDA, NORTHERN LESSER ANTILLES

SCOTT C. PEDERSEN, PETER A. LARSEN, HUGH H. GENOWAYS,
MATHEW N. MORTON, KEVEL C. LINDSAY, AND JERRY CINDRIC

ABSTRACT

Five species of bats are known to occur on the Lesser Antillean island of Barbuda—*Noctilio leporinus*, *Monophyllus plethodon*, *Brachyphylla cavernarum*, *Tadarida brasiliensis*, and *Molossus molossus*. During the present study, two additional species of bats—*Artibeus jamaicensis* and *Natalus stramineus*—were added to the chiropteran fauna of the island. Although the ecological diversity of Barbuda is limited, this bat fauna matches those of islands in the region such as Antigua, Nevis, and St. Kitts. It is proposed that this biodiversity of bats is maintained because of the geology of Barbuda provides ample roosting sites and access to freshwater in caves, bluff faces, and sinkholes. The conservation of the chiropteran fauna of Barbuda, therefore, depends on the protection of these geological resources.

Key words: *Artibeus jamaicensis*, Barbuda, Chiroptera, Lesser Antilles, *Natalus stramineus*

INTRODUCTION

The island of Barbuda (17°40'N, 61°50'W) lies 40 kilometers north of its political partner Antigua. The island is mostly undeveloped and has a human population of about 1,500. Bats are the only native mammals found on Barbuda (Varona 1974), but no systematic study of the bats of the island has been published. Two groups of scientists have been working on the bat faunas throughout the Lesser Antilles since 1993. Teams led by Mathew Morton (1994-99, 2005) focused upon roost surveys on a number of islands throughout the region aiming to provide resources for local conservation efforts and further study, whereas teams associated with Scott Pedersen (1993-2006) have focused primarily on the distribution and zooge-

ography of bat species and how bat populations have fluctuated in response to ecological disasters (Pedersen et al. 1996, 2003, 2005, 2006, 2008). The following combined data summarize work performed during a six-day visit to Barbuda in the second week of February 1994 (Morton and Lindsay), four days during the first week of June 2003 (Pedersen, Larsen, and Genoways), and six days of cave surveys performed in February 2007 (Cindric 2007). Prior to this work five species of bats (*Noctilio leporinus*, *Monophyllus plethodon*, *Brachyphylla cavernarum*, *Tadarida brasiliensis*, and *Molossus molossus*) had been reported from Barbuda in scattered publications. Breuil and Masson (1991) list *Artibeus jamaicensis* from Barbuda in their compilation

of the distribution of bats in the Lesser Antilles, but the source of their record is unclear. Therefore, we document *Artibeus jamaicensis* and *Natalus stramineus* on

Barbuda, giving the island a known chiropteran fauna of seven species.

METHODS

Study Area.—Barbuda is approximately 161 square kilometers in size. The island can be divided into two topographic units: The Highlands, with the highest point at 42 m, is composed primarily of horizontally bedded Pliocene limestone deposits (Flemming and McFarlane 1998) forming a karst plateau that runs along the east coast of the island; and the Marginal Plain, which flanks the plateau on all sides except the east and is relatively flat, rarely exceeding 10 m above sea level. Barbuda and Antigua lie on the Pleistocene Barbuda Bank of which approximately 80% lies at 40 m or less below sea level. Barbuda's climate is subtropical with temperatures ranging 18–45°C and rainfall averaging 100 cm per year. There are standing bodies of brackish water, and access to surface freshwater before human occupation was probably limited to temporary ponds following heavy rains. Harris (1965) classified the majority of vegetation on the island as evergreen woodland, which tends to be xerophytic and of low height. The island is covered primarily with cacti, agave, and thorny trees that form dense thickets. There are scattered palm trees that are often associated with sinkholes, and introduced mango and banana trees appear in very small numbers (Watters et al. 1984).

Survey Techniques.—Bats were captured in roosts by hand or by using a variety of hand-nets, mist nets, and lightweight cargo nets. Mist netting for bats was limited due to the lack of habitat in which mist netting is effective, that is, concentrations of fruit trees or sources of open water. Although mist netting was done in most of the caves that were visited (Fig. 1), only two nights of netting were conducted in foraging habitats (8 nets at Dominic, 3 June 2003; 5 nets in the vicinity of Gun Shop Cave, 4 June 2003). Bats that were captured and released were measured and examined (weight, forearm, reproductive status, tooth wear, presence of scars, and external parasites), whereas the remaining bats were taken as museum voucher specimens.

Voucher Specimens.—Seventy-six voucher specimens of seven species of bats—*Noctilio leporinus*, *Monophyllus plethodon*, *Artibeus jamaicensis*, *Brachyphylla cavernarum*, *Natalus stramineus*, *Tadarida brasiliensis*, and *Molossus molossus*—were collected during our survey and deposited at the Museum of Texas Tech University. Eighty-one individuals were captured and released. A survey of existing collections in three museums (American Museum of Natural History, Museum of Comparative Zoology, and the National Museum of Natural History) revealed an additional 52 vouchers resulting from earlier incidental work done on Barbuda. Forearm and cranial measurements were taken with digital calipers. All measurements are recorded in millimeters and all weights are in grams.

Cave Surveys.—Rather than carry out a randomized search along transects for potential roosts, we focused upon “likely” sites for the presence/absence of roosting bats. Caves are common on Barbuda and several important roosts were visited in 1994, 2003, and 2007. More extensive descriptions of several of the roosts listed below are presented elsewhere (unpublished 1994 Report to Environmental Action Group Biodiversity Programme by M. Morton), whereas the formal cave surveys of 2007 by J. Cindric will be published separately. Several caves deserve mention here and are discussed below.

Indian Cave is a prehistoric archaeological site near Two Feet Bay along the northeast coast of Barbuda (Figs. 1, 2, 3). The entrance to this cave is near the top of a low cliff and leads directly into a round side chamber called the Drop Cave, which extends into a large chamber about 10 m high that was occupied by *A. jamaicensis* and *B. cavernarum* in 1994, and by *N. leporinus* in 1994, 2003, and 2007. Continuing past the Drop Cave, there is a short east-west passage in which Amerindian petroglyphs can be viewed—these

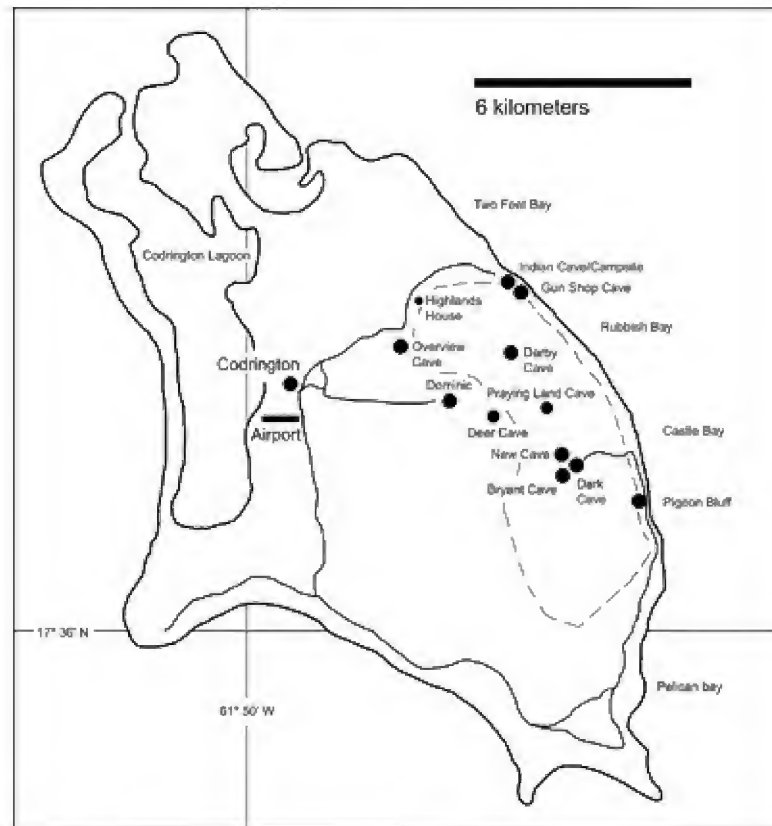


Figure 1. Map of Barbuda indicating various cave roosts and netting localities.

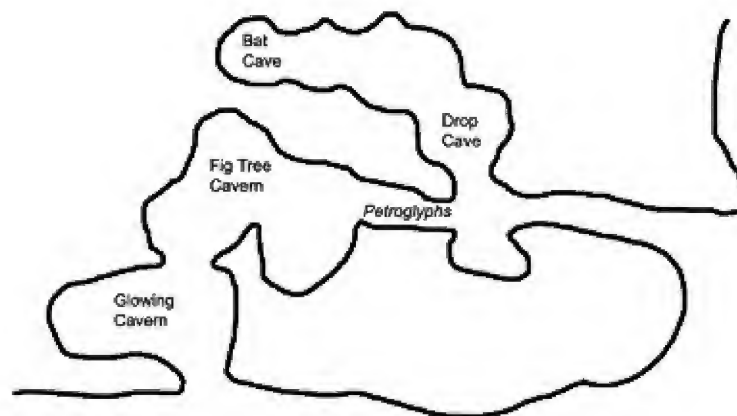


Figure 2. Indian Cave (*after* Morton et al. 1994).



Figure 3. Escarpment facing Two Feet Bay (looking south). Photo: J. Cindric.

petroglyphs being the only ones found on either Antigua or Barbuda. Additional chambers were searched for the presence of bats without result.

Darby Cave lies 5.5 kilometers ENE of Codrington Village (Figs. 1, 4) and was sketched and briefly described by Hummelinck (1979). This cave is a collapsed sinkhole 20 m high and 100 m in diameter with vertical sides, one of which is undercut by some 10 m, hence the term “cave”, and is full of lush vegetation, lianas, and tall trees including palmetto palm. Ferns and birds were abundant in the sinkhole in direct contrast to the surrounding scrub habitat. Stalactites descend from the cliff overhang and one very large flat-topped stalagmite measured 2.5 m high, 1 m in diameter and was tinged greenish white. A fossilized shark tooth fragment (*Carcharodon megalodon*; Pliocene) was excavated from the northern end of this cave in May 1997 (Flemming and McFarlane 1998). Darby Cave was not visited in 2003, however *Artibeus* was observed at this cave in both 1994 and 2007.

Back on Praying Land Cave is a large sinkhole 14 m deep and 46 m in diameter (Fig. 1). The roots

of a large fig tree penetrate the limestone ceiling and drop to the bottom of the cave in a tangle several meters across. In 2007, a medium-sized group of *Brachyphylla*, estimated at 300 to 400 animals, was observed in this cave.

Deer Cave is another sinkhole with a single 1 m wide entrance hole in its ceiling which drops into a 5 m high chamber (Figs. 1, 5). There were several passages in this cave all with low ceilings and some slight movement of air. Several hundred *Natalus* were observed in this cave in 2007, either clustered in a loose grouping or hanging individually.

New Cave has been described as a large cavern system with numerous entrances and side tunnels extending 30-40 m in several directions away from the central chamber (Figs. 1, 6). Large numbers of *M. plethodon*, *N. leporinus*, *B. cavernarum*, and *A. jamaicensis* were either captured or observed in this cave in 1994. Although this cave was described as being very near to Dark Cave by Morton and Lindsay in 1994, neither the 2003 nor the 2007 teams could locate this particular cavern.



Figure 4. Darby Cave. Photo: J. Cindric.



Figure 5. Mr. Kenric Joseph standing over the entrance of Deer Cave. Photo: J. Cindric.

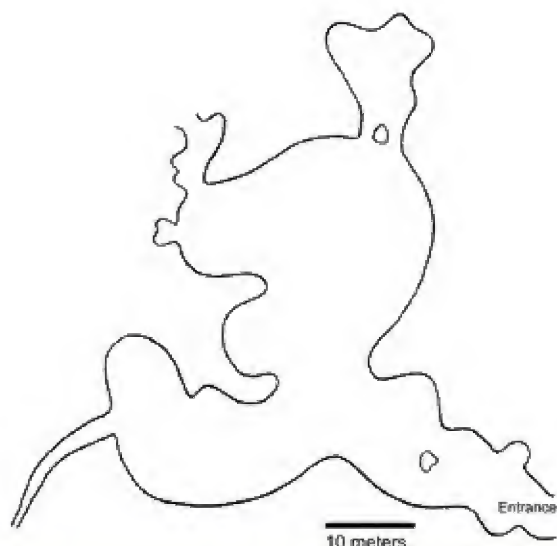


Figure 6. New Cave (after Morton et al. 1994).

Dark Cave is a very large cavern that lies north-east of Bryant Cave (Figs. 1, 7). Hummelinck (1979) described in considerable detail the interior of Dark Cave and Cindric, Boling, and Joseph surveyed this cavern in great detail in February 2007 (Cindric 2007; Fig. 7). Dark Cave consists primarily of an elongate, 180 m long tube with several smaller side chambers, some of which exhibit 12 to 15 m high domed ceilings that were occupied by hundreds of large quietly roosting bats, quite probably *Artibeus*. Three pools of fresh water are located along the west wall of this cavern and each teemed with a wide variety of invertebrates during the 2003 and 2007 surveys. The 2007 survey calculated that these pools are located nearly 25 m underground and are very close to sea level. This source of fresh water may be important for the large populations of bats in the cave and may have served as a water source for Amerindians, given that their artifacts have been found nearby this cave. Large numbers of *M. plethodon*, *N. stramineus*, *B. cavernarum*, and *A. jamaicensis* were either captured or observed in 2003 and 2007. Of note, bats were not present in this cave in 1994, suggesting that the bats move among the numerous caves on this island.

Bryant Cave lies approximately 3.25 km SSE of Darby Cave (Fig. 1) and is reported to communicate with Dark Cave immediately to the northeast, although we did not explore this claim. Bryant Cave is a large



Figure 7. Dark Cave (after Cindric 2007).

collapsed sinkhole with vertical sides composed of fractured rock and fissures that presumably offer roosting opportunities for bats. The stagnant pool of water in this sinkhole may also provide a critical water supply for those bats and birds that inhabit the walls of this feature. *Natalus stramineus* was hand-captured at this locality in 1994 but no bats were noted during the 2003 visit.

Given the geology of the island, there would appear to be an abundance of potential roosting sites for either frugivorous or insectivorous bats on Barbuda. The karst plateau of The Highlands is riddled with sinkholes and fissures that have been largely unexplored. For example, there are some deep fissures northeast of Highland House at the north end of the island that were observed by one of the authors (Lindsay) to be full of unidentified bats. Rock formations stretch along

several kilometers of the eastern coast of Barbuda from Two Feet Bay in the north down to Pelican Bay in the south. These formations include hundreds of rock shelters, erosion cavities, fissures, and additional sinkholes. Numerous *T. brasiliensis* were either observed or extracted from crevices along this formation during our surveys and several *N. leporinus* were extracted from dilution pockets in a limestone cliff at Pigeon

Bluff near Castle Bay in 2003. Overview Cave is located about 2.5 km from the east coast in the north-west face of the Highlands escarpment (Watters et al. 1984). The entrance of the cave is approximately 1.7 m high and 4 m wide. The chamber penetrates about 7 m into the escarpment and light reaches most parts of the cave. Pregill et al. (1994) presented a photograph of this cave.

SPECIES ACCOUNTS

Noctilio leporinus mastivus (Vahl 1797)

Specimens examined (11).—Overview Cave, 3.5 km NE of Codrington, 1 (NMNH); Pigeon Bluff, 17°36'52.7"N, 61°44'9.2"W, 3 m, 10 (TTU).

Specimens captured/released (8).—Indian Cave, 17°40'04"N, 61°46'10"W, 1; Pigeon Bluff, 7.

Additional records.—No specific locality (Husson 1960:154); Indian Cave (2007 photograph-Cindric).

Husson (1960) first reported the greater bulldog bat from Barbuda based on four individuals collected at an unspecified locality by Hummelinck in July 1955. Length of forearm and cranial measurements of five male and five female specimens from Barbuda are given in Table 1. Males averaged significantly larger than females in all measurements taken. For five measurements, the significance level was $P \leq 0.001$. For mastoid breadth the significance level was $P \leq 0.01$, and for length of forearm and length of maxillary tooththrow the significance level was $P \leq 0.05$. In fact, in only the latter two measurements do the ranges of the measurements of the sexes overlap. Davis (1973) assigned circum-Caribbean specimens to the subspecies *N. l. mastivus*, which was originally described from St. Croix, U. S. Virgin Islands. Measurements of the specimens from Barbuda are within the range of those given by Davis (1973) for a sample of 21 females from the West Indies; therefore, we have followed this arrangement here.

Seventeen *N. leporinus* were collected as a group on 2 June 2003 using a modified cargo net suspended

under a solution pocket in a limestone block/escarpment called Pigeon Bluff at Castle Bay. At this point, the cliff formed an overhang that was at least 6 m deep and permitted the research team full access to the solution pocket in which the greater bulldog bats were located. This vertical cavity was about 3 m above the floor of the overhang, 0.5 m in diameter, and at least 2 m deep. Although the overhang area was well illuminated, the bats at the top of the solution pocket could not be seen without the aid of a flashlight. This colony consisted of 10 males and seven females. One male and one female were juveniles, six of the females were lactating, and four of the males were scrotal. Lactating females and their young were intermixed with scrotal males indicating an absence of sexual or age partitioning in this colony. Average length of testes of five adult males was 7.6 (5–11). Five adult males weighed an average of 61.0 (55.4–69.9), whereas five adult females averaged 51.2 (49.3–53.0).

The specimen that was captured by hand in the Overview Cave roost on 17 January 1983 was an adult male (length of forearm, 86.1) with enlarged testes. *Noctilio leporinus* were observed in Indian Cave in both 1994 and 2003, and a non-reproductive adult male was caught by hand there on 10 February 1994 (length of forearm, 87.3; weight, 66.2). During the 2007 survey, nine fishing bats were photographed in a domed portion of Indian Cave. Fishing bats were observed in 2003 flying among sea grape trees along the base of a rock face at Gun Shop Cliff, possibly hawking insects. The animals flew close to the ground (<1 m) and deftly avoided several mist nets that were set in the area.

Table 1.—Length of forearm and seven cranial measurements (in mm) for seven species of bats occurring on the West Indian island of Barbuda.

Statistics, catalog numbers, and sex	Length of forearm	Greatest length of skull	Condylobasal length	Zygomatic breadth	Postorbital constriction	Mastoid breadth	Length of maxillary tooththrow	Breadth across upper molars
<i>Noctilio leporinus mastivus</i>								
Males								
N	5	5	5	5	5	5	5	5
Mean	88.1	28.8	25.5	19.9	7.2	18.6	10.6	12.7
Range	(86.5-90.9)	(27.7-29.7)	(25.2-26.1)	(19.7-20.3)	(7.2-7.3)	(17.6-20.1)	(10.5-10.7)	(12.4-12.9)
± SE	±0.76	±0.42	±0.17	±0.10	±0.02	±0.46	±0.04	±0.08
Females								
N	5	5	5	5	5	5	5	5
Mean	85.0	26.6	24.2	18.7	6.9	17.0	10.4	12.2
Range	(82.6-86.6)	(26.4-27.0)	(24.1-24.2)	(18.6-18.9)	(6.8-7.0)	(16.7-17.2)	(10.2-10.5)	(12.0-12.3)
± SE	±0.66	±0.11	±0.02	±0.06	±0.03	±0.10	±0.06	±0.05
<i>Monophyllus plethodon luciae</i>								
Males								
N	4	5	5	5	5	5	5	5
Mean	42.4	23.4	21.7	10.4	4.7	10.2	8.1	5.7
Range	(41.5-42.7)	(23.0-24.0)	(21.3-22.3)	(10.3-10.6)	(4.6-4.8)	(10.0-10.4)	(7.9-8.4)	(5.5-5.8)
± SE	±0.29	±0.20	±.20	±0.06	±0.04	±0.07	±0.09	±0.05
Females								
N	5	5	5	5	5	5	5	5
Mean	42.5	23.2	21.4	9.8	4.7	9.7	7.9	5.4
Range	(41.6-44.0)	(22.7-24.2)	(20.9-22.2)	(9.6-10.2)	(4.5-4.9)	(9.5-10.2)	(7.7-8.0)	(5.3-5.6)
± SE	±0.40	±0.28	±0.24	±0.11	±0.06	±0.15	±0.05	±0.05
<i>Brachyphylla cavernarum cavernarum</i>								
Males								
N	5	5	5	5	5	5	5	5
Mean	65.4	32.1	28.9	17.2	6.2	14.9	11.3	11.9
Range	(63.7-67.6)	(31.6-32.3)	(27.7-29.3)	(16.7-17.6)	(5.9-6.4)	(14.5-15.5)	(11.0-11.5)	(11.8-12.0)
± SE	±0.65	±0.13	±0.31	±0.18	±0.09	±0.17	±0.08	±0.04
Females								
N	5	5	5	5	5	5	5	5
Mean	66.9	32.0	28.4	17.1	6.4	14.6	11.1	11.5
Range	(63.7-69.6)	(31.0-32.7)	(27.7-29.0)	(16.6-17.6)	(6.2-6.6)	(14.2-15.0)	(10.6-11.5)	(11.2-11.9)
± SE	±1.06	±0.33	±0.23	±0.20	±0.08	±0.13	±0.15	±0.12
<i>Artibeus jamaicensis jamaicensis</i>								
Male								
TTU 101758	59.9	28.1	24.8	16.8	7.0	14.8	9.7	12.4
Females								
N	5	5	5	5	5	5	5	5
Mean	60.7	28.4	24.9	16.8	7.3	14.8	9.8	12.6
Range	(59.5-61.9)	(28.0-28.7)	(24.2-25.3)	(16.5-17.1)	(7.1-7.5)	(14.3-15.1)	(9.6-10.1)	(12.3-12.9)
± SE	±0.39	±0.11	±0.19	±0.12	±0.09	±0.14	±0.09	±0.14

Table 1 (cont.).

Statistics, catalog numbers, and sex	Length of forearm	Greatest length of skull	Condylobasal length	Zygomatic breadth	Postorbital constriction	Mastoid breadth	Length of maxillary tooththrow	Breadth across upper molars
<i>Natalus stramineus stramineus</i>								
Males								
N	5	5	5	5	5	5	5	5
Mean	40.8	17.1	15.6	8.6	3.1	7.7	7.4	5.7
Range	(40.0-41.6)	(16.9-17.2)	(15.4-15.8)	(8.5-8.7)	(3.1)	(7.5-8.0)	(7.4-7.5)	(5.6-5.7)
± SE	±0.31	±0.07	±0.07	±0.03	±0.00	±0.10	±0.02	±0.02
Females								
N	5	5	5	5	5	5	5	5
Mean	40.7	16.9	15.6	8.4	3.1	7.7	7.3	5.5
Range	(39.7-41.5)	(16.7-17.5)	(15.5-16.0)	(8.2-8.7)	(3.0-3.2)	(7.4-7.8)	(7.3-7.4)	(5.4-5.7)
± SE	±0.32	±0.14	±0.10	±0.09	±0.03	±0.09	±0.02	±0.05
<i>Molossus molossus molossus</i>								
Males								
AMNH 213935	37.9	16.7	14.7	10.4	3.4	9.7	5.8	7.2
TTU 101778	38.7	16.5	14.8	10.1	3.4	9.7	5.5	7.1
Females								
N	5	5	5	5	5	5	5	5
Mean	37.4	16.0	14.2	9.9	3.2	9.2	5.5	6.8
Range	(36.1-38.8)	(15.8-16.2)	(13.9-14.5)	(9.8-10.2)	(3.2-3.3)	(9.0-9.4)	(5.1-5.7)	(6.4-7.1)
± SE	±0.48	±0.07	±0.10	±0.09	±0.02	±0.07	±0.11	±0.16
<i>Tadarida brasiliensis antillarum</i>								
Males								
N	7	7	7	7	7	7	7	7
Mean	38.8	16.0	14.8	9.2	3.6	8.8	5.6	6.4
Range	(37.8-40.7)	(15.3-16.4)	(14.1-15.2)	(8.4-9.6)	(3.5-3.7)	(8.5-9.1)	(5.3-5.7)	(5.6-6.7)
± SE	±0.36	±0.13	±0.16	±0.18	±0.03	±0.08	±0.06	±0.17
Females								
TTU 101779	38.4	16.0	14.8	9.1	3.6	8.9	5.7	6.3
TTU 101781	36.7	15.1	14.1	9.4	3.5	8.9	5.4	6.6

***Monophyllus plethodon luciae* Miller 1902**

Specimens examined (17).—Codrington, 3 blocks north of airport, 3 (NMNH); Dark Cave, 17°37'26.1"N, 61°45'12.1"W, 24 m, 8 (TTU); Dominic, 4.3 km E Codrington, 17°38'26.6"N, 61°47'05.8"W, 14 m, 6 (TTU).

Specimens captured/released (11).—Dark Cave, 3; Dominic, 7; New Cave, 1.

Additional record.—Dark Cave (Schwartz and Jones 1967).

The previous report of this species on Barbuda was based on a single female obtained by Hummelinck and deposited in Rijksmuseum van Natuurlijke Historie in Leiden. Forearm and cranial measurements of a sample of five males and five females are given in Table 1. Males averaged larger than females in all measurements except length of forearm in which females were larger and the postorbital constriction in which the means were the same. These differences were significant for three of the breadth measurements, with the sexes differing at the $P \leq 0.01$ level for zygomatic breadth and breadth across upper molars and at the $P \leq 0.05$ level for mastoid breadth. When compared

with a sample of three males and two females from Guadeloupe (Baker et al. 1978) and three males from Antigua (Pedersen et al. 2006), these measurements of bats from Barbuda show almost complete overlap, with the exception of the breadth across the upper molars, which was larger in the three specimens from Antigua. A single male from Nevis (Pedersen et al. 2003) and a single female from Montserrat (Pedersen et al. 1996) fall within the range of variation of measurements of the sample from Barbuda for all measurements except mastoid breadth, which was 0.2 and 0.3, respectively, smaller than the smallest individual of the corresponding sex from Barbuda. We follow Schwartz and Jones (1967) in placing all populations of this species from St. Lucia northward in the Lesser Antilles in the subspecies *M. p. luciae*, but we recognize that the variation represented among samples in the northern Lesser Antilles call for a re-evaluation of geographic variation in this species now that larger samples are available.

According to Schwartz and Jones (1967), Hummelinck's field notes for the female that he obtained indicate that "the bat was found dead near the entrance of Dark Cave," but no other bats were observed in the cave. No *M. plethodon* were identified in Dark Cave during the 1994 visit, but 11 non-reproductive and lactating females were collected there in 2003 with mist nets set across the main chamber. They were seen hanging in small groups from the ceilings of side chambers. None of these bats were seen roosting near the freshwater pools. Two males and a female from Codrington were taken on 17 January 1983 under unknown circumstances. One of those males had enlarged testes. A single non-reproductive female was caught in New Cave in 1994 (weight, 13.4; forearm, 40.7). Thirteen *M. plethodon* were captured along a road leading into the orchard at Dominic in 2003. A single 2 m by 2 m mist net filled the space between the acacia trees growing along both sides of the road at this point. The acacias and other dry thorny vegetation were relatively low in this area, not exceeding 4 m in height, but the road did form a distinct flyway for the bats. Captures on 2 and 3 June 2003 included six males and 18 females, six of which were lactating and 12 which were non-reproductive. The average weight of six adult males was 15.6 (15.2-17.2), with testes lengths averaging 3.2 (3.0-4.0). The mean weight for 15 of the 18 females was 15.1 (12.5-18.4).

***Brachyphylla cavernarum cavernarum* Gray 1834**

Specimens examined (41).—Dominic, 4.3 km E Codrington, 17°38'26.6"N, 61°47'05.8"W, 14 m, 16 (TTU); Two Feet Bay, Gun Shop Cliff, 17°40'03"N, 61°46'00"W, 11 m, 4 (NMNH); no specific locality, 21 (NMNH).

Specimens captured/released (33).—Dominic, 4.3 km E Codrington, 17°38'26.6"N, 61°47'05.8"W, 14 m, 21; Indian Cave, 17°40'04"N, 61°46'10"W, 8; New Cave, 4.

Additional record.—Back on Praying Land Cave, 17°38'23"N, 61°46'01"W (2007 photograph - Cindric).

The Antillean fruit-eating bat has been reported from Barbuda by previous authors, but it has never been associated with a specific locality (Miller 1913; Anthony 1918; Swanepoel and Genoways 1978; Hall 1981). Table 1 presents the length of forearm and seven cranial measurements for a sample of five males and five females from Barbuda. The only measurement in which there was a significant difference between the sexes was breadth across the upper molars, with males being larger ($P \leq 0.05$). In general, males were larger in all other cranial measurements except postorbital constriction in which the females averaged broader. Females also had longer forearms. The measurements of our sample from Barbuda match closely those samples of the subspecies *B. c. cavernarum* presented by Swanepoel and Genoways (1978); therefore, we assign the material from Barbuda to the nominate subspecies, which has a type locality of St. Vincent.

As on many islands in the northern Lesser Antilles, *B. cavernarum* is an obligate cave dweller and occupies large cave systems. Entire colonies may move among several caves on an island on a seasonal basis or may split into separate male and female colonies when pups and juveniles are present (Pedersen et al. 1996, 2003). In February 1994, 22 *B. cavernarum* were collected by hand and with mist-nets in Indian, Dark, and New caves, but only females were taken in Dark Cave. Of the 22 individuals, 10 were males and 12 were females, including three juvenile males and one juvenile female. Average weight and forearm length of three of the adult males was 43.8 (40.3-47.2)

and 65.2 (64.2–67.1), whereas the weight and forearm length of nine adult females was 44.9 (36.3–54.8) and 66.3 (64.7–71.3). In June 2003, individuals of *B. cavernarum* were clearly observed in large numbers up in the high domed ceilings of Dark Cave. The floor of the cave was littered with several *B. cavernarum* skulls and disarticulated skeletons.

On the night of 4 June 2003, 37 *B. cavernarum* were mist netted while they foraged among mixed fruit trees (primarily mango) in a semi-abandoned fruit orchard at Dominic. The mangos, which were nearly ripe, were quite small in size. The grove of fruit trees was surrounded by low acacia and other thorny native plants. In Back on Praying Land Cave, a group of 300 to 400 Antillean fruit-eating bats was observed and photographed in 2007. This large sinkhole had at least four ceiling openings and the bats were located in one dark recess of the cave. The colony was disturbed by the human presence, but the bats did not leave the cave.

Of the 20 females captured at Dominic, six were lactating, eight were pregnant, and six were non-reproductive. None of the 17 males appeared to be reproductively active, and testis lengths for six adult males were 4, 5, 5, 6, 6, and 7. Four of the females gave birth in the holding bags—three of the young were alive and the fourth was dead the following morning. One of the newborn that remained associated with its mother was a female that weighed 11.9 and had a forearm of 35.0, whereas its mother weighed 41.6 and had a forearm of 65.6. The remaining two living newborns (female followed by male) and the dead newborn male had the following measurements, respectively: weight, 10.6, 10.7, 8.1; length of forearm, 34.7, 31.3, and 26.4. Average weight for the 17 males was 47.6 (41.2–48.5). Average weight for five post-partum lactating females was 42.5 (40.6–44.1). One of the eight pregnant females weighed 62.1 and the other seven were so near-term that they were released without collecting body mass data from them. The average weight of three non-reproductive females was 42.8 (39.7–45.6). Many of these animals had minor wounds to the plagiopatagium covering the metacarpals on one wing or the other. Upon removal from the mist net, one male with a forearm of 67.0 exhibited a very deep puncture wound to the chest wall that penetrated the rib cage. The diameter and depth of this wound ruled out the possibility of this being the result of fighting with conspecifics.

Artibeus jamaicensis jamaicensis Leach 1821

Specimens examined (11).—Codrington, 3 blocks north of airport, 1 (NMNH); Dominic, 4.3 km E Codrington, 17°38'26.6"N, 61°47'05.8"W, 7 (TTU); Two Feet Bay, Gun Shop Cliff, 17°40'03"N, 61°46'00"W, 2 (NMNH); no specific locality, 1 (MCZ).

Specimens captured/released (3).—Indian Cave, 17°40'04"N, 61°46'10"W, 3.

Additional record.—Darby Cave, 17°39'26.85"N, 61°46'31.96"W (2007 photograph - Cindric).

These specimens represent the first record of the common and widespread Jamaican fruit-eating bat from Barbuda. Breuil and Masson (1991) list *Artibeus jamaicensis* from Barbuda in their compilation of the distribution of bats in the Lesser Antilles, but the source of their record is unclear in their references. Table 1 presents the measurements for one adult male and five adult females. The measurements of the male fall within the range of those of the females for all variables except postorbital constriction in which the male is smaller than all of the females. Genoways et al. (2001) reviewed Antillean populations of the Jamaican fruit bat based upon morphometrics and presence/absence of M3/m3, and Phillips et al. (1989), Pumo et al. (1996), Carstens et al. (2004), and Larsen et al. (2007b) presented genetic data for these populations. These studies support the use of the subspecific name *A. j. jamaicensis* for populations on Barbuda. Additionally, Larsen et al. (2007b) generated and phylogenetically analyzed cytochrome-b DNA sequence data from six specimens of *A. jamaicensis* collected during the 2003 survey (TTU 101758 – TTU 101763). These specimens share a common haplotype, which is also present within populations of *A. jamaicensis* distributed throughout the Greater and Lesser Antilles. Such results further support the hypothesis of a recent colonization by *A. jamaicensis* into the Caribbean during the late Pleistocene (Phillips et al. 1991; Genoways et al. 2005; Larsen et al. 2007b).

In direct contrast to the numerical dominance of *Artibeus* on other islands in the northern Lesser Antilles (15–49% of all captures; Pedersen et al. 2007), *Artibeus* makes up only 5.9% of all capture records on Barbuda (cave and foraging habitat) and contributes only 9.6%

of all captures at a foraging site at Dominic. On Barbuda, *Brachyphylla* would seem to be the numerically dominant fruit/omnivore bat at 38% of all records and 60% of all mist-net captures at Dominic.

Three males were captured by hand in 1994 in Indian Cave and the cliff face adjacent to it. Average weight and forearm of these three bats are 38.4 (36.2–42.0) and 58.9 (56.3–61.0). The five adult females and one adult male captured in 2003 were mist netted in the same abandoned mango orchard (Dominic) where we took *B. cavernarum*. During the 2007 cave survey, three clusters of Jamaican fruit-eating bats were easily observed under a ledge in Darby Cave. Each of these clusters was composed of approximately 25 individuals. The other specimens examined are three adult males taken in 1983 by a field party from the National Museum of Natural History and an adult female taken under unknown circumstances (no date) and deposited in the Museum of Comparative Zoology at Harvard University.

The scrotal male netted on 4 June 2003 had a testis length of 7 and weighed 33.7. The three males taken on 19 January 1983 weighed 37.5, 41.5, and 46. One of the females taken on 4 June 2003 was lactating and weighed 33.7. The other four females were pregnant when captured but one delivered a baby in the holding bag. The newborn male weighed 11.4 and its post-partum mother weighed 31.6. The other females each carried a single embryo that measured 18, 22, and 30 in crown-rump length—pre-partum weights on these females were 43.3, 41.8, and 50.7, respectively.

Of the six individuals examined for dental characters, four were missing both upper third molars but possessed both lower third molars. The other two individuals were missing both upper third molars as well as both third lower molars. The absence of the upper M3s matches the pattern of this geographically variable character in other populations of *A. j. jamaicensis*, but the percentage of individuals with the lower m3 present is less than that reported in other samples of this species (Genoways et al. 2001).

Natalus stramineus stramineus Gray 1834

Specimens examined (12).—Dark Cave, 17°37'26.1"N, 61°45'12.1"W, 24 m, 12 (TTU).

Specimens captured/released (20).—Bryant's Cave, 17°37'25.00"N, 61°45'18.86"W, 1; Dark Cave, 17°37'26.1"N, 61°45'12.1"W, 24 m, 2; New Cave, 17.

Additional record.—Deer Cave, 17°38'14"N, 61°47'05"W (2007 photograph - Cindric).

These specimens represent the first record of the Lesser Antillean funnel-eared bat from Barbuda. There are conflicting views on the specific relationship among populations of the large funnel-eared bats occurring in the Lesser Antilles, Greater Antilles, Mexico, and Central America (Varona 1974; Hall 1981; Koopman 1993; Arroyo-Cabrales et al. 1997; Dávalos 2005). Dávalos (2005) and Tejedor et al. (2005) presented evidence that unrecognized taxa of *Natalus* exist within currently named populations in the West Indies. Goodwin (1959), in his revision of members of the subgenus *Natalus*, restricted the type locality of *Natalus stramineus* to Antigua rather than Lagoa Santa, Minas Gerais, Brazil, as was done by earlier authors. This decision was reconfirmed by Handley and Gardner (1990) and Tejedor (2006). Tejedor (2006) restricted *N. stramineus* to the northern Lesser Antilles, ranging from Dominica to Anguilla, and in a canonical analysis of external and cranial characters, demonstrated that “the sample from Dominica is morphometrically distinct from that of the remaining islands.” Although Tejedor (2006) did not use it, the name *N. s. dominicensis* Shamel (1928) is available for the population on Dominica, leaving the nominate subspecies, *N. s. stramineus*, as the appropriate name to apply to the other populations in the northern Lesser Antilles, including those on Barbuda.

Table 1 presents length of forearm and seven cranial measurements for five males and five females collected on Barbuda in 2003. The sexes differed significantly only in length of the maxillary tooththrow ($P \leq 0.01$) in which males were larger. In three measurements (condylobasal length, postorbital constriction, and mastoid breadth), the sexes averaged the same size. In the remaining four measurements, males averaged slightly larger than females. Of the 17 animals netted in Dark Cave in 1994, six were non-reproductive males and 11 were non-reproductive females. An adult male and female hand-collected at Dark Cave in 1994 weighed 6.2 and 5.2, respectively, and had forearms lengths of 40.7 and 39.2, respectively. On 3

June 2003, eight males and six females were netted in Dark Cave, four of these females carried embryos with crown-rump lengths of 16, 20, 20, and 20. Four of the males captured on the same date had measurable testis lengths of 1, 1, 2, and 2. The two reproductively inactive females weighed 4.3 and 4.6, whereas the pregnant females weighed 4.5, 5.8, 6.1, and 6.5. The six males weighed an average of 4.8 (4.5–5.1).

Natalus stramineus is an obligate cave dweller (Goodwin 1970), and was found in many of the large caves visited in 1994 and in large numbers at Dark Cave in 2003. It seems likely that *N. stramineus* needs dark, moist caves in which to roost (Blankenship 1990; also see McFarlane 1986); certainly, it has been proposed that the high humidity of caves used as roosts is necessary to prevent dehydration of the delicate wing membranes of these bats (Goodwin 1970). All of the *N. stramineus* collected in 2003 in Dark Cave were snared in an old mist net draped over the entrance into a side tunnel located approximately 10 m from a well-lit antechamber where humidity was 100% and the temperature exceeded above-ground surface temperature (33°C). We did not explore this 1-m diameter side-tunnel, but the cavity extended a considerable distance beyond the reach of our headlamps.

In the sinkhole, Deer Cave, three passages lead away from the five-meter high central chamber. Two of the passages were hot, low, dusty cavities that required some excavation to permit travel. The third passage was different from the other two in being rocky and it had discernible air movement. After a hands-and-knees crawl of 15 m there was a small domed chamber wherein there were several hundred funnel-eared bats. In one photograph (Cindric) of a portion of this colony, at least 120 individuals can be counted, most of which are hanging separately. The passage became too small to pass beyond this chamber, although the air movement would indicate an additional opening to the surface.

Roost conservation is an obvious priority for this species, yet with Barbuda's wealth of large moist caves and its small human population, populations of *N. stramineus* do not seem to be threatened and it is not surprising that the Barbuda population is among the largest that we have observed in the northern Lesser Antilles (Pedersen et al. 1996, 2003, 2005, 2006; Genoways et al. 2007a, 2007b; Larsen et al. 2007a, 2007b).

Tadarida brasiliensis antillarum (Miller 1902)

Specimens examined (22).—Codrington, 3 blocks north of airport, 3 (NMNH): Gun Shop Cave, 17°40'03"N, 61°46'00"W, 11 m, 8 (TTU); Two Feet Bay, 17°40'08.0"N, 61°46'8.4"W, 15 m, 1 (TTU); no specific locality, 10 (NMNH).

Specimen captured/released (1).—Gun Shop Cave, 17°40'03"N, 61°46'00"W, 11 m, 1.

Shamel (1931) was the first to report the Brazilian free-tailed bat from Barbuda, basing his report on 11 individuals collected from an unspecified location by H. S. Branch between 16 to 29 August 1903. Miller (1902) described this taxon as a species with a type locality at Roseau, Dominica, but Schwartz (1955) reduced this taxon to a subspecies of the widespread *Tadarida brasiliensis*. This subspecies has a geographic range extending from Puerto Rico to St. Vincent (Genoways et al. 2001). Table 1 presents the length of forearm and cranial measurements of a sample of seven adult males and two adult females from Barbuda. All of the measurements of one of the females (TTU 101779) fall within the range of variation displayed by the males, whereas two measurements (length of forearm and greatest length of skull) of the second female (TTU 101781) fall below the range of the males, and two other measurements (condylobasal length and postorbital constriction) fall at the lower limit of the range of variation of the males.

This bat has a very broad Neotropical distribution, although it may only occur at moderate densities throughout the Lesser Antilles (Blankenship 1990). No individuals of this species were taken during our work in 1994 on Barbuda, but we did collect eight males and two females in 2003. No individuals of *T. brasiliensis* were captured in mist nets set in foraging areas on Barbuda. Nine of the 10 individuals were netted in Gun Shop Cave as they returned from their first foraging bout of the evening or as they moved from other small caves in this area on the northeast coast. The male from Two Feet Bay was extracted from a narrow crevice in a rocky cliff face on the northeast coast. We observed several other individuals in nearby fissures, but the bats were located so far back in each crevice that they could not be reached. We do not know under what circumstances the seven male and three female

specimens were taken in 1903 or how two males and one female were obtained in Codrington on 19 January 1983.

None of the seven females for which we have reproductive data evinced any gross reproductive activity on the following dates: 19 January 1983, 1; 4 June 2003, 2; 16 August 1903, 2; 20 August 1903, 1; 29 August 1903, 1. The testes lengths of males taken on 7 June averaged 3.3 (2-4). One male and two females collected between 20 and 25 August exhibited open phalangeal epiphyses, although their forearm lengths were essentially of adult size, 38.2, 36.9, and 36.5, respectively. Seven males weighed an average of 9.3 (8.3-10.6) and two females weighed 9.0 and 9.3.

Molossus molossus molossus (Pallas 1766)

Specimens examined (11).—Codrington Village, 2 (AMNH); Dominic, 4.3 km E Codrington, 17°38'26.6"N, 61°47'05.8"W, 14 m, 6 (TTU); Gun Shop Cave, 17°40'03"N, 61°46'00"W, 11 m, 2 (TTU); no specific locality, 1 (NMNH).

Koopman (1968) first reported Pallas's mastiff bat from Barbuda based on two specimens from Codrington Village that also were examined for our study. Table 1 presents the length of forearm and seven cranial measurements for a sample of two males and five females from Barbuda. The two males were larger than the range of measurements of the females in four measurements (greatest length of skull, condylobasal length, postorbital constriction, and mastoid breadth),

whereas the values for the sexes overlap for the other four measurements. Husson (1962) restricted the type locality of *M. molossus* to the island of Martinique, which lead Dolan (1989) to apply the name *M. m. molossus* to this species throughout the Lesser Antilles.

These free-tailed bats were observed emerging from buildings in Codrington near dusk during 1994 and 2003, but even here they did not seem to be as abundant as on other islands that we have visited in the northern Lesser Antilles. We netted six adult females in the abandoned mango orchard called Dominic on 4 June. These bats were taken in the same nets as *A. jamaicensis* and *B. cavernarum*. An adult male and female were netted inside Gun Shop Cave along with eight Brazilian free-tailed bats. It appeared that the bats had already fed and were using the cave as a night roost in 2003 because searches of the cave during the day revealed no bats. The circumstances under which the other specimens were taken are unknown to us.

None of the seven females taken on 4 June 2003 evinced reproductive activity nor did the single female taken on 5 March 1963. A male taken on 5 March 1963 had testes that measured 5.5, and the male from 4 June 2003 had testes that measured 6. A female taken on 20 August 1903 had wing epiphyses that were not completely fused but its length of forearm was of adult size (38.1). The male from 2003 weighed 11.5, whereas the seven females had an average weight of 10.2 (8.8-11.6).

DISCUSSION

With our addition of two species (*Artibeus jamaicensis* and *Natalus stramineus*), the bat fauna of Barbuda has the same seven species as Antigua (Pedersen et al. 2006) just to the south, with which it would have been connected during the Pleistocene when sea levels were much lower than today (Pregill and Olson 1981). The fauna has representatives of four chiropteran families—Noctilionidae, Phyllostomidae, Natalidae, and Molossidae, including one carnivore, *N. leporinus* (fish and insects; Brooke 1994); three insectivores, *N. stramineus*, *M. molossus*, and *T. brasiliensis*;

and three phyllostomids, two of which are primarily frugivores: *A. jamaicensis* and *B. cavernarum* (fruit, flowers, and leaves), and *M. plethodon*, which is a specialized nectarivore.

Nevertheless, the paucity of chiropteran taxa on both Barbuda and Antigua distinguishes these islands from nearby Guadeloupe, which is situated upwind of both islands. Although present on Guadeloupe, no *Myotis* have been reported from Barbuda, Antigua, or Montserrat despite 20 years of extensive efforts on

those islands (Pedersen et al. 1996, 2006). Another insectivorous species missing from Barbuda, Antigua, and Montserrat is *Eptesicus guadeloupensis*, which is currently known only from Guadeloupe (Genoways and Baker 1975). Three species of fruit bat—*Ardops nichollsi*, *Sturnira thomasi*, and *Chiroderma improvisum*—have been reported from Montserrat (50 km WSW) and Guadeloupe (75 km SSE), but have not been found on either Barbuda or Antigua (Baker and Genoways 1976; Jones and Baker 1979; Genoways 1998). Most notable by its absence from Barbuda and Antigua is *Ardops*, a common tree-roosting fruit bat found throughout the Lesser Antilles that is quite common on nearby islands: Montserrat (~15% of frugivore captures; Pedersen et al. 1996) and St. Kitts (~36% of frugivore captures; Pedersen et al. 2005). Of the five Pleistocene island banks to the north of Guadeloupe (Saba, St. Martin, St. Kitts, Montserrat, and Barbuda), *Ardops nichollsi* is absent only from the Barbuda Bank (Antigua and Barbuda; Baker and Genoways 1978; Jones 1989; Koopman 1989).

To the human eye, Barbuda is an unlikely place to find even seven species of bats—ecological diversity is limited, the island has a very low profile with the highest elevation being 42 m, there is little or no available surface freshwater, the dry, thorny vegetation seems to offer little in the way of native fruits, and the island is relatively small with an area of 161 sq km. There was no effort made to quantify the number and distribution of columnar cacti or agave during these surveys, however, these plants may provide a significant nutritional resource for plant visiting bats on Barbuda. The human imprint on Barbuda is insignificant, although the island has been heavily grazed by sheep and goats. As such, it was quite surprising to us that the chiropteran fauna of Barbuda matches that of Antigua (Pedersen et al. 2006). Antigua is a larger island (279 sq km) with a higher profile (405 m) giving it considerably more ecological diversity than Barbuda. In addition to native fruits, there are a large number of introduced tropical fruit trees on Antigua. Before human occupation, Antigua may have lacked any appreciable amount of surface freshwater, but now there are a number of open reservoirs. However, Antigua has been heavily impacted by human activity that has altered much of the native vegetation and decreased its ecological diversity.

The diverse bat fauna on Barbuda is likely a result of the islands' geology, which provides ample caves, bluffs, and sinkholes that serve as roosting sites for cavity and crevice roosting species. These sinkholes and caves offer open bodies of freshwater in some cases. Many of the sinkholes serve as refugia that support a great diversity of trees. In 1994, 20 out of the 27 sites searched (74%) were found to contain bats or evidence of bats. cursory examination of likely caves and deep crevices in 1994 revealed insectivorous bat guano, and molossid bats were observed in about 75% of the cavities searched. Most of the simple rock shelter caves or bluff faces had a single species in residence but all of the large caves housed 2 or 3 species. In 1994, *A. jamaicensis* was the most commonly encountered species during searches of various roost types, demonstrating a tolerance for a wide range of roosts. However, when the 1994 and 2003 surveys are combined, *B. cavernarum* was encountered or netted more frequently than any other species, and it dominated (59%) mist net captures. Arguably, the omnivorous habits of *B. cavernarum* and the wealth of cave roosting opportunities make this species one of the more successful species on Barbuda.

The internal architecture of Dark Cave clearly deserves further study and the ease of access provides an excellent opportunity for studying subterranean biological systems. We observed but did not document in any detail a variety of microclimates and associated structural differences with which different species of bats seemed to be associated. As on other islands, *N. stramineus* was located in small side tunnels, whereas *M. plethodon* and *B. cavernarum* were typically located on broad expanses of cave roofs or in large domed ceilings. Similar patterns of roosting have been found in large, multi-species caves on the adjacent islands of Antigua, Nevis, and St. Maarten (Pedersen et al. 2003, 2006, 2008). The bat fauna of Barbuda is a very significant part of the islands' natural heritage, comprising the entire native terrestrial mammal fauna. Because of the significance of caves, rock shelters, and rock outcrops to the bat fauna, all efforts should be directed to keeping as many of these areas as possible in an undisturbed state.

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Addresses of authors:

SCOTT C. PEDERSEN

*Department of Biology and Microbiology
South Dakota State University
Brookings, SD 57007
Scott_Pedersen@sdstate.edu*

PETER A. LARSEN

*Department of Biological Sciences and Museum
Texas Tech University
Lubbock, TX 79409
peter.larsen@ttu.edu*

HUGH H. GENOWAYS

*W436 Nebraska Hall
University of Nebraska State Museum
Lincoln, NE 68588
hgenoways1@unl.edu*

MATHEW N. MORTON

*Durrell Wildlife Conservation Trust
Trinity, Jersey, JE3 5BP
United Kingdom
Matthew.Morton@durrell.org*

KEVEL C. LINDSAY

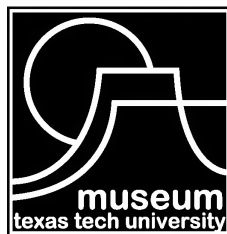
*Natural Resources Management
24 Rogers Avenue
Brooklyn, NY 11216
kcl927@yahoo.com*

JERRY CINDRIC

*401 South Harrison Street
Olathe, Kansas 66061
CALECIN@aol.com*

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